EXPERIMENT 1

MEASUREMENTS WITH A MULTIMETER

Structure

1.1 INTRODUCTION

In a physics laboratory, we need to perform various measurements. To carry out the measurements of electrical quantities like ac-dc voltages, currents and resistances, we use a multipurpose instrument called **multimeter**. A multimeter can be an analogue multimeter or a digital multimeter (DMM). It is an essential instrument in every physics laboratory because it is useful for fault finding in electrical circuits and testing of components. For example, suppose you discover that a circuit is not working even though all connections are correct and all devices and components in it are working. Then the fault could lie in one of the connecting wires. You can use the multimeter to test the continuity of the connecting wires by measuring their resistance. By doing this, you can locate the faulty wire and replace it. At times the fuse in the power supply circuit of the instrument may blow out and so there is no supply of power to the circuit components. You can use the multimeter to test a fuse as well.

Since a multimeter can be used to measure ac or dc voltage and current, it can be used instead of a voltmeter or an ammeter. You know that the conventional voltmeters and ammeters have fixed mode (ac or dc) and fixed range of operation (e.g., 0-1 V, 0-10 V or 0-1 mA, 0-1 A, etc.), so you need to use different meters for different mode and ranges. However, a multimeter has a built-in range selector. So a multimeter can be used to measure in all the ranges, such as 0-1 V, 0-10 V or 0-1 mA, 0-1 A (and ac or dc mode) by just selecting a proper mode and range.

You will appreciate that the multimeter is a very useful instrument. Therefore, you must learn how to use it properly. In this experiment you will learn how to use a multimeter for various measurements and also the precautions you should take while handling it.

Expected Skills

After doing this experiment, you should be able to

- identify various functions available on a given multimeter and select appropriate function as required;
- use a multimeter to measure resistances, ac and dc voltages and currents;
- test the continuity of a wire and a fuse with the help of a multimeter; and
- list the precautions to be taken while using a multimeter and components.

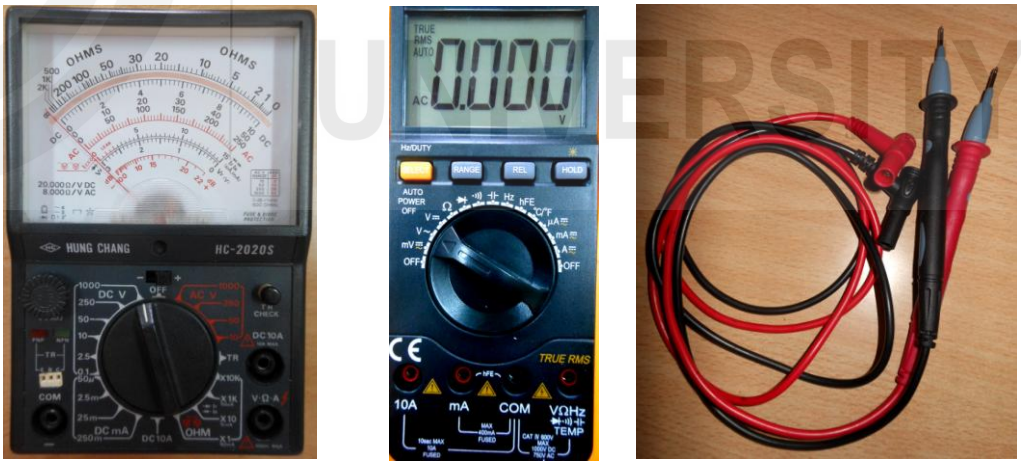
For doing this experiment, you will need following apparatus and components.

Apparatus required

Multimeter with leads, resistors, rheostat, connecting wires, fuse socket with fuse wire, ac signal generator and dc power supply.

1.2 KNOW YOUR MULTIMETER

Multimeters are distinguished on the basis of their display mechanisms. In an analogue multimeter (Fig. 1.1a), the readings are displayed by the movement of a needle on a scale dial, while in a digital multimeter (Fig. 1.1b), they are indicated by digits on the display panel. Otherwise, their functions are identical.



(a) **(b)** **(c)**

Fig. 1.1: **Front panels of a) analogue; b) digital multimeter; c) multimeter leads**.

A multimeter has two leads (connectors) as shown in Fig. 1.1c that are to be inserted in the terminals provided on the front panel. As a convention the red lead is used for positive polarity while the black lead corresponds to negative polarity. You should follow the proper colour code while inserting the leads in the multimeter: The other end of the lead cable is usually a pointed probe, which can be touched at the points in the circuit or across the ends of the device whose measurements are to be done.

Before you actually start using the multimeter, you should get familiar with its front panel. For this, do the following activity.

Activity

a) Take the multimeter available in your lab. List all the controls on the panel and write their functions and compare them with Fig. 1.1a or 1.1 b as the case may be. You may refer to the manual accompanying the multimeter.

b) Identify the input terminals (and their polarity) to be used for various measurements like resistance, voltage, current (ac-dc, high voltage, high current) etc.

c) Find out the relevant specifications of the multimeter such as its operating temperature, storage temperature, battery voltage and battery type from its manual.

d) Write down the ranges of the resistance, ac/dc voltages and currents that can be measured with this multimeter.

Once you are familiar with the multimeter, you can use it for different measurements. While using the multimeter, you should always keep in mind the following precautions:

PRECAUTIONS WHILE HANDLING A MULTIMETER

- **If you do not know the source of voltage (ac or dc), then keep the meter in the ac voltage range.**
- **While taking any measurement, start from the maximum range corresponding to the electrical quantity being measured.**
- **While measuring current, the multimeter should be connected in series.**
- **While measuring voltage, it should be connected in parallel.**
- **While measuring high voltages, do not touch any part of the multimeter.**
- **When the multimeter is not in use, switch it off.**
- **While using an analogue multimeter in resistance range, first make the zero adjustment.**

1.3 MEASUREMENTS WITH A MULTIMETER

Now that you are familiar with the multimeter, in general, you are ready to use it for various measurements described below.

1.3.1 Resistance Measurement

(a)

(b)

Fig. 1.2: **a) Range overflow; b) proper range selection for resistance measurement**.

To measure a resistance using a **digital multimeter (DMM)** follow the steps given below:

1. Insert the **red lead** in **VΩ** terminal and **black lead** in **COM** terminal of the DMM.
2. Select, say 20 Ω range by selector switch.
3. Keep the resistor to be measured horizontally on a wooden (electrically non-conducting) table top. Touch the pointed probes of the leads on two ends of the resistor to be measured.
4. If the value of resistor is higher than 20 Ω. You will just see digit "1" on the left most position on the display panel (see Fig. 1.2a). It indicates overshooting of the range. In such case select a higher range, say, 200 Ω.
5. If the display is still showing digit "1", then keep selecting higher ranges till you get some reading on the display. In Fig. 1.2b, an example of reading obtained in case of 150 Ω resistor on 200 Ω range is shown.

In some digital multimeters, you will find a facility of "Auto" range. In such case, you do not have to change the range manually. The multimeter will automatically select the proper range as per the value of the resistance being measured.

When you are using an **analogue multimeter for measuring resistor value remember that the scale of resistance is opposite to that of the voltage scale. Means the zero of resistance scale is on the extreme right side of the circular scale.**

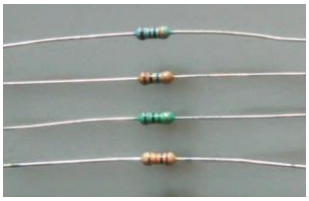
Now follow the steps given below to measure an unknown resistance.

1. Set the range selector switch on the Ω scale in the highest range;
2. Insert **black lead** in **COM** input terminal and **red lead** in **VΩ** input terminal.
3. Make the **zero adjustment** as follows: Short circuit the read and black leads, i.e., make them touch each other. The pointer on the graduated scale will move to the extreme right end. Now rotate the knob marked 'zero adj' or 'ohms zero' to adjust the pointer to exact zero on the scale.
4. Now connect the unknown resistance between the leads, and note the value of the resistance on the meter. If the value falls within a lower range then select that range for greater accuracy.

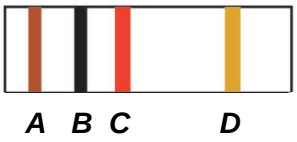
You may have learnt about reading the colour codes of resistor in your school physics course. If not, here we give the information, in brief in Table 1.1 and the box ahead. It will be useful for identifying the value of the resistor from its colour code.

READING THE RESISTANCE VALUE FROM THE COLOUR CODES

Typically the resistors are made up of carbon or platinum films deposited on a cylindrical insulating base. They are coated with epoxy to avoid any environmental effect on the resistance value. To indicate the value of the resistance, typically **four** coloured stripes are printed on the body of the resistor as shown in Fig. 1.3a.



(a)



(b)

Fig. 1.3: **a) Carbon film resistors; b) colour coding on the resistor**.

Particular values are assigned to different colours as listed in Table 1.1. This is called the ***colour code***.

The colour code is read from left to right starting with the side that has a stripe closer to the edge (*A* in Fig. 1.3b) Read from left to right, the first three stripes (*A*, *B*, *C*) tell us the **value** of the resistance. The fourth stripe *D* gives the **tolerance code** which tells us the extent of error in the resistance. So, the resistance of a resistor is:

$$R = AB \times 10^{C}\ \Omega \pm D\%$$

where *A, B, C* and *D* are as shown in Fig. 1.3b. Their values are determined from Table 1.1.

For example, let stripe *A* be yellow (4), *B* be violet (7), *C* be red (2) and *D* be gold (5%) on a resistor, then the value of its resistance is

$$R = 47 \times 10^{2} \pm 5\% = 4700\ \Omega \pm 5\% = 4.7\ k\Omega \pm 5\%$$

Table 1.1: Resistor Colour Codes

Value	Colour
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Grey
9	White
Tolerance Codes	
1%	Brown
5%	Gold
10%	Silver

Now, take several resistors of known resistance values in different ranges and some with unknown values. Measure their values with both types of multimeters and tabulate your results in Observation Table 1.1.Compare your readings with the colour codes printed on the resistors.

Observation Table 1.1: Measurement of Resistance

Sl.No.	Resistance measured with analogue multimeter (Ω)	Resistance measured with digital multimeter (Ω)	Expected value of resistance as per colour code (Ω)
1			
2			
3			
4			

You can also use the multimeter in its resistance measurement mode to check the continuity of a wire or test a fuse.

1.3.2 Testing of Wire Continuity and Fuse

You know that a connecting wire or fuse wire is a good conductor and has low resistance. However, if the wire is broken at any point, no current will pass through it because there will be infinite resistance between the two ends of the broken wire. This basic principle gives us the method for checking the continuity of the wire or a fuse with the help of a multimeter.

Procedure of Testing Continuity

Take a wire or fuse which you want to test and connect its ends to the black and red leads of the multimeter as done in the case of resistance measurement process. Select the lowest resistance range. You should get a zero ohm reading. In some multimeters you will also hear a “beep” if there is continuity in the wire. If there is a break in the wire, you will get infinite (or very large) resistance reading. You should discard such a wire. In case of fuse, you should replace the fuse wire.

1.3.3 Direct and Alternating Current Measurements

A multimeter can be used to measure both alternating and direct currents. In this part of the experiment you will build appropriate circuits for taking these measurements. Follow the steps listed below for each measurement.

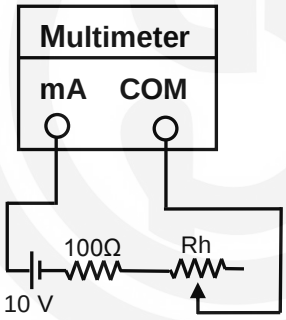


Fig. 1.4: **Circuit for direct current measurement.**

A. DC (direct current) measurement

1. Connect a circuit containing a dc power supply, a resistor, a rheostat and a multimeter as shown in Fig. 1.4. (You are familiar with the symbols of electrical components used in the circuit. In case of any doubt, discuss with your Cousellor.) Always remember that for current measurement, the multimeter is connected in **“SERIES”** with the circuit through which the current is flowing.

2. Insert **red lead** in the **mA** input terminal and **black lead** in the **COM** terminal. Select the highest range of **DC current**. If the value of the current falls in a lower range, select the appropriate range.

Remember that the expected current (which you can estimate by calculating the voltage/resistance in the circuit) should not exceed the maximum permissible current in the multimeter.

3. Keep the rheostat slider to the extreme end away from the terminal where power supply is connected, so that it provides maximum resistance.

4. Now switch on the power supply and measure the current in the circuit by choosing appropriate current range.

5. Next slide the slider of the rheostat a little so that its resistance reduces. Again read the value of the current. This value will be higher than in the earlier case. **Remember that, while reducing the resistance, if the current exceeds the selected range, you should select the higher current range.**

6. Repeat Step 5 till the rheostat slider reaches the other end. In this situation, the resistance offered by the rheostat is 0 Ω.

7. Now note the current value.

8. From Ohm's Law, you can work out that the current value should be

$$I = \frac{10\ \text{V}}{100\ \Omega} = 100\ \text{mA}$$

9. Compare your observed value with this expected value.

10. Turn off the power supply and disconnect the components.

B. AC (alternating current) measurement

1. Replace the power supply in Fig. 1.4 by an ac voltage source.
2. Insert red lead in the **mA** input and the black lead in the **COM** input.
3. Set range selector knob to highest range for **AC current**. If the value of the current falls in a lower range, select the appropriate range.
4. Follow Steps 3 to 10 described in A above.

1.3.4 DC and AC Voltage Measurements

A. DC voltage measurement

1. Connect the circuit as shown in Fig. 1.5.
2. Insert **red lead** in the **VΩ** input terminal and the **black lead** in the **COM** input terminal. You will observe that the multimeter is connected in **"PARALLEL"** with the device (100 Ω resistor in this experiment) across which the voltage is being measured.
3. Set range selector knob to an appropriate **DC V** position. If the voltage to be measured is not known, set range selector at the highest dc voltage range and reduce the range, if necessary, for a satisfactory reading.
4. Follow steps 3 to 6 listed in 1.3.3 (A) and record the voltage values.

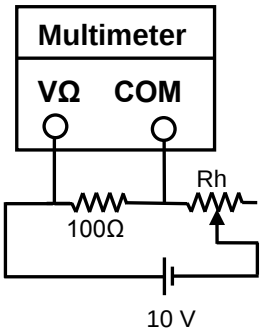


Fig. 1.5: **Voltage measurement using a multimeter.**

B. AC voltage measurement

Replace the dc voltage source by an ac voltage source in Fig. 1.5. Follow the steps given for dc voltage measurement with the only difference that the range selector switch should be set in **AC V** position.

YOU MUST REMEMBER THAT

- **for current measurement, the multimeter (used as ammeter) is connected in series with the circuit.**
- **for voltage measurement, the multimeter (used as voltmeter) is connected in parallel with the component across which we wish to measure voltage.**